A Novel On-Line Treatment Verification System Based on Silicon Strip Detectors for Measuring 2D Axial Dose Maps in Radiotherapy

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on behalf of the Radia Project
University of Seville (Spain)

ICTR-PHE 2012
Geneva, Switzerland
March 2nd, 2012

Introduction: Motivation & Objective

➢ Motivation:

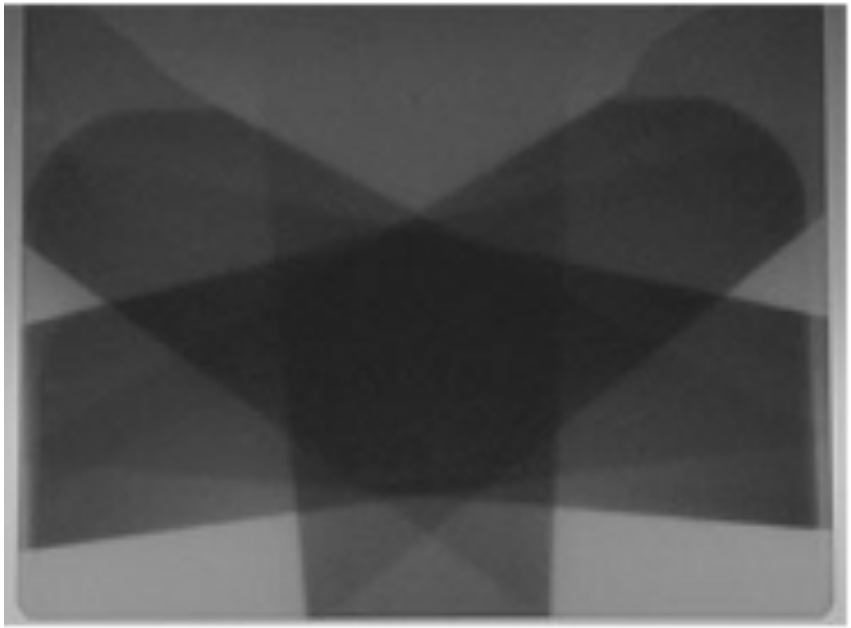
Cancer is the second most frequent cause of death in developed countries. At present, although surgery is the most effective way to remove the malignant tissue, when it is combined with radiation therapy improves the cure rate.

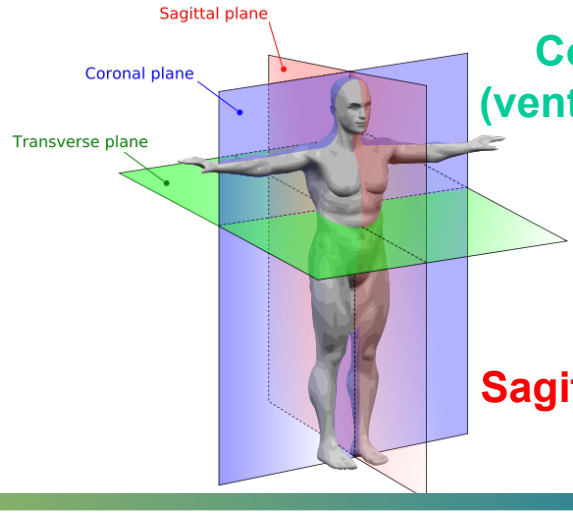
➢ Objective:

Characterization of a silicon strip detector dedicated to 2D dose measurements in the **axial plane of a phantom** for the verification of **complex radiation therapy** treatment plans.

Introduction: Motivation & Objective

Film dosimeters: traditional detectors for verifying treatment plans dose distribution





Coronal plane (ventral and dorsal)

Axial plane (inferior and superior)

Sagittal plane

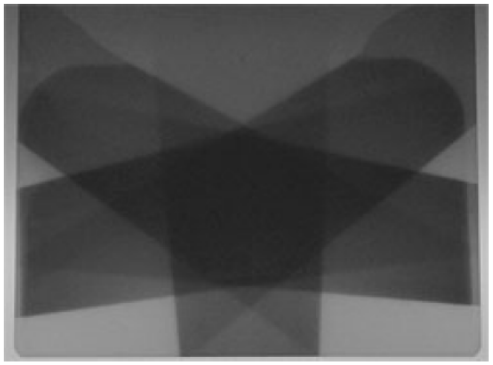
Film dosimetry used as 2D dosimeters :

Advantages: high spatial resolution (sub-mm), good uniformity, axial plane

Disadvantages: Unusable as on-line detectors and time consuming

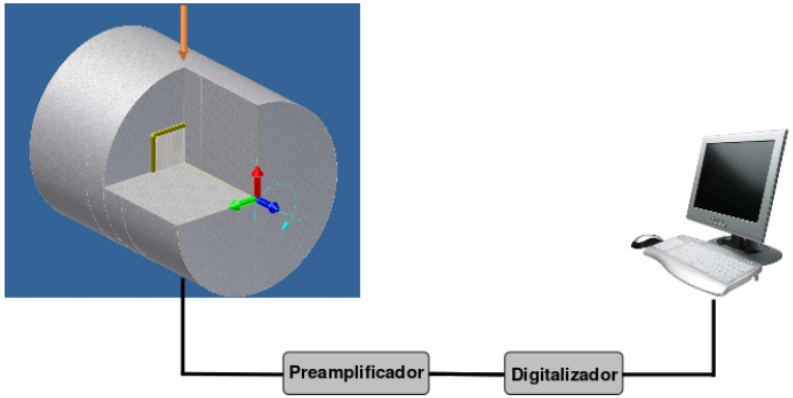
Introduction: Motivation & Objective

Traditional detectors



Radiographic films

New detection systems



	Film dosimeters	2D commercial digital detectors	New detection systems
On-line	no	✓	✓
Spatial resolution	✓	poor	✓
2D detectors	✓	✓ yes Not monolithic!	✓
Axial plane	✓	no	✓

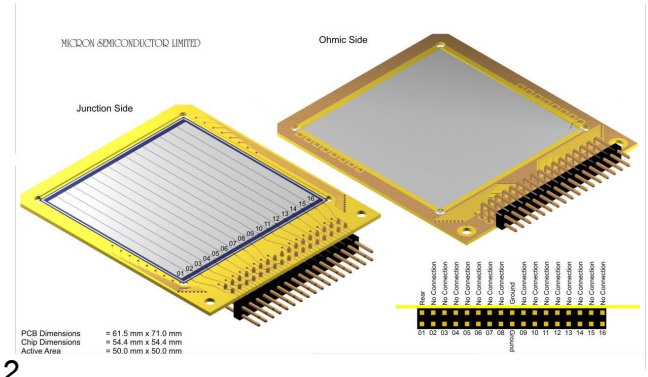
Necessity of developing **new detection systems** that **enhance the traditional ones**, and are able to verify in a simple and accurate way complex treatment plans

- **inexpensive**
- **radiation hard**
- **easy to use**

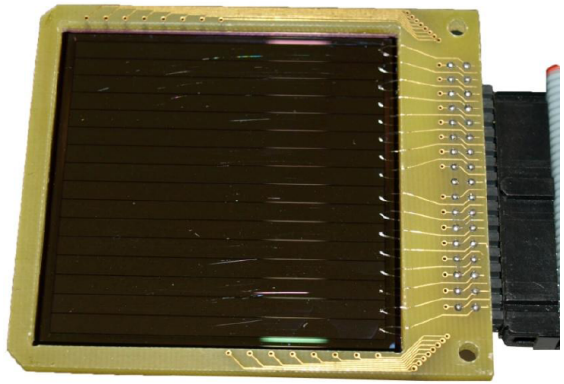
Materials & Methods

The Detector

- **Model W1-SS 500** from **Micron Semiconductor Ltd**.
- Silicon Strip Detector – SSSSD (Single Sided Silicon Strip Detector)



Thickness: 500 µm
Number of Strips: 16
Strip Width: 3 mm
Active Area: 50x50 mm²



Commercial detector
Low cost
Easy to handle
High sensibility
High counting rate

The Accelerator

- **Measurements carried out at the Virgin Macarena University Hospital in Seville**
- Siemens Oncor™ and Primus™

Materials & Methods

Two phantoms made out of polyethylene were designed and built to calibrate the detector and perform measurements

Slab Phantom:

Perpendicular to beam direction

Calibration & Characterization

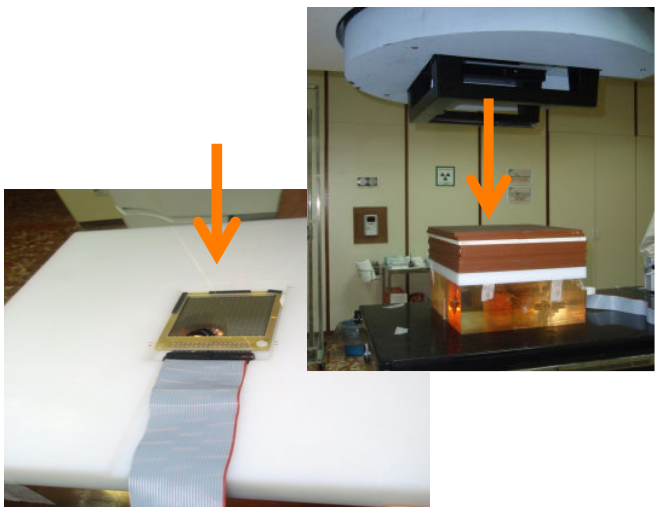
Linearity, Uniformity, Penumbra, Percent Depth Dose: PDD

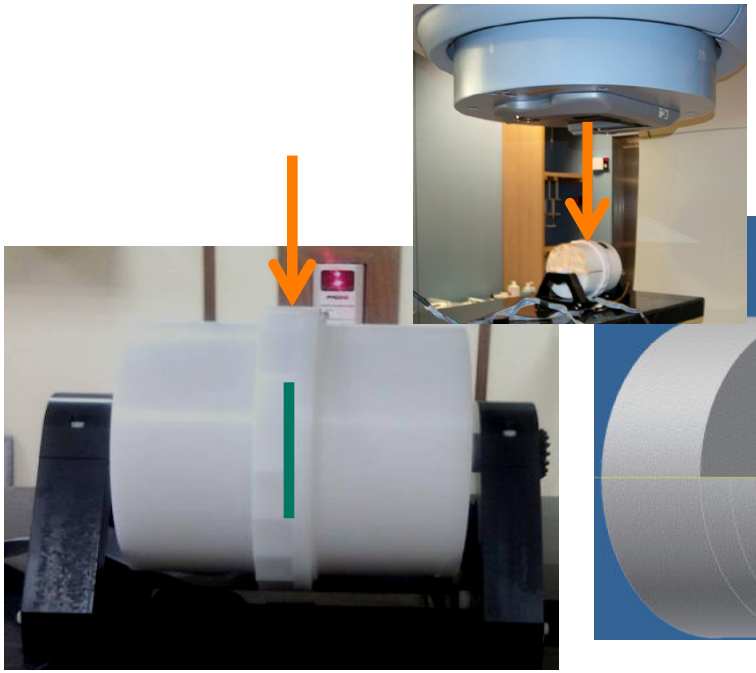
Cylindrical Rotating Phantom:

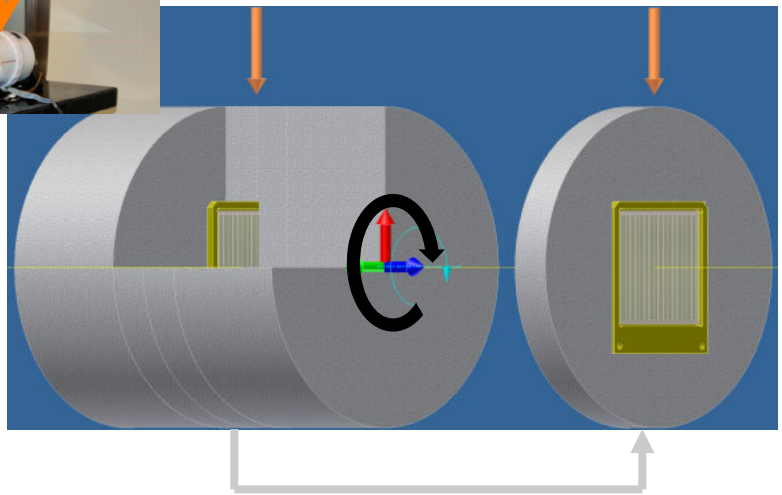
Axial plane and can rotate with respect to the beam axis

Similar geometry to part of the human body (tissue equiv.)

Angular response characterization, dose maps measurements.







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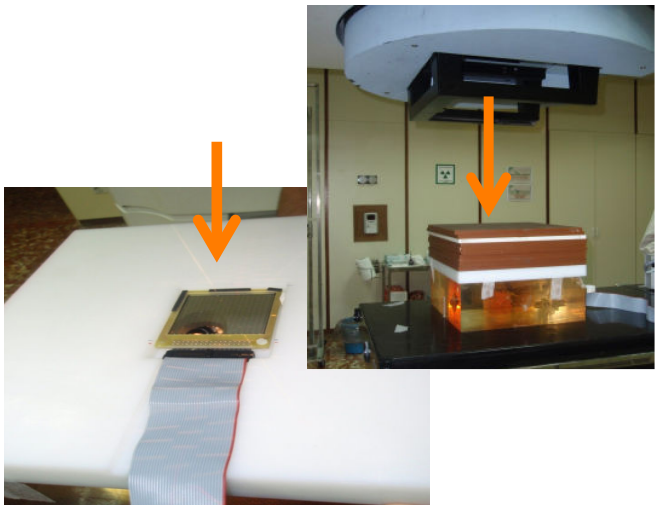
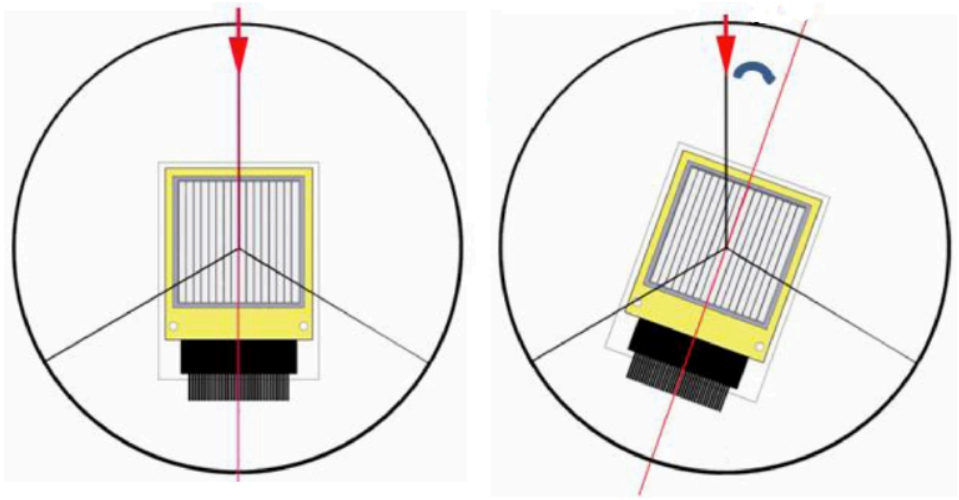
Angular response characterization, dose maps measurements.

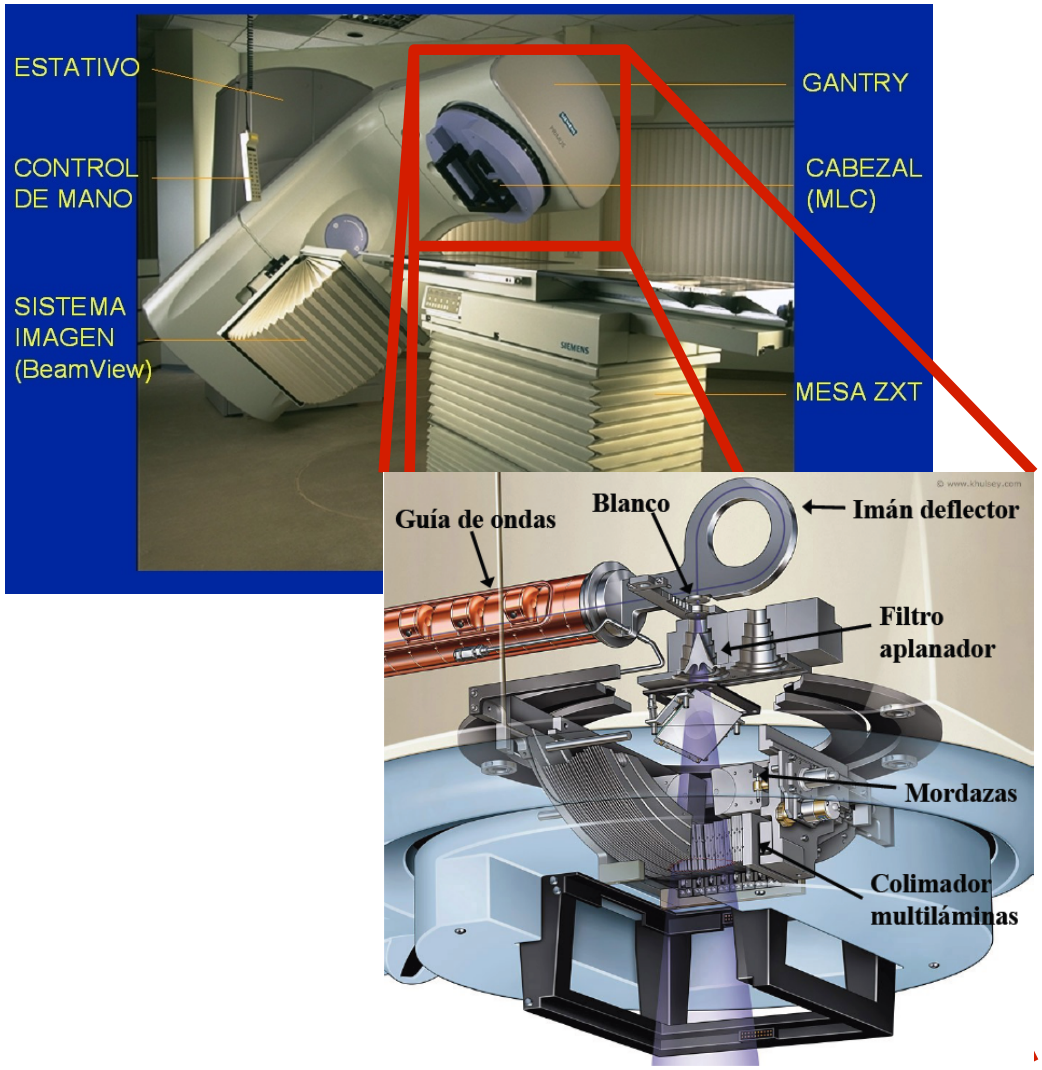
2D Axial Dose Map reconstructed with an in-house algorithm based on the Radon Transform



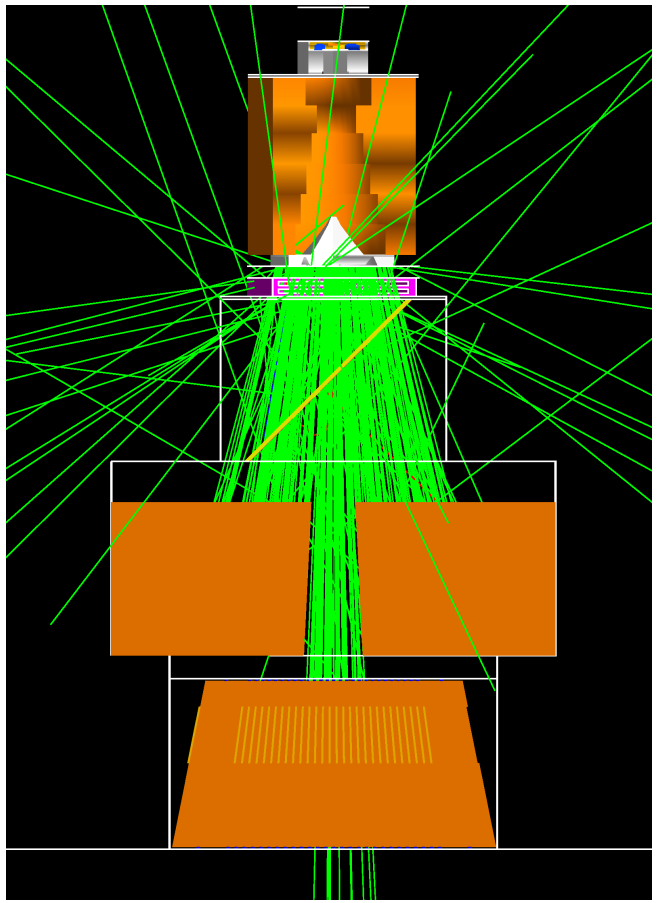


Monte Carlo Simulations

Performed with the Geant4 toolkit



Geometry Model



Monte Carlo Simulations

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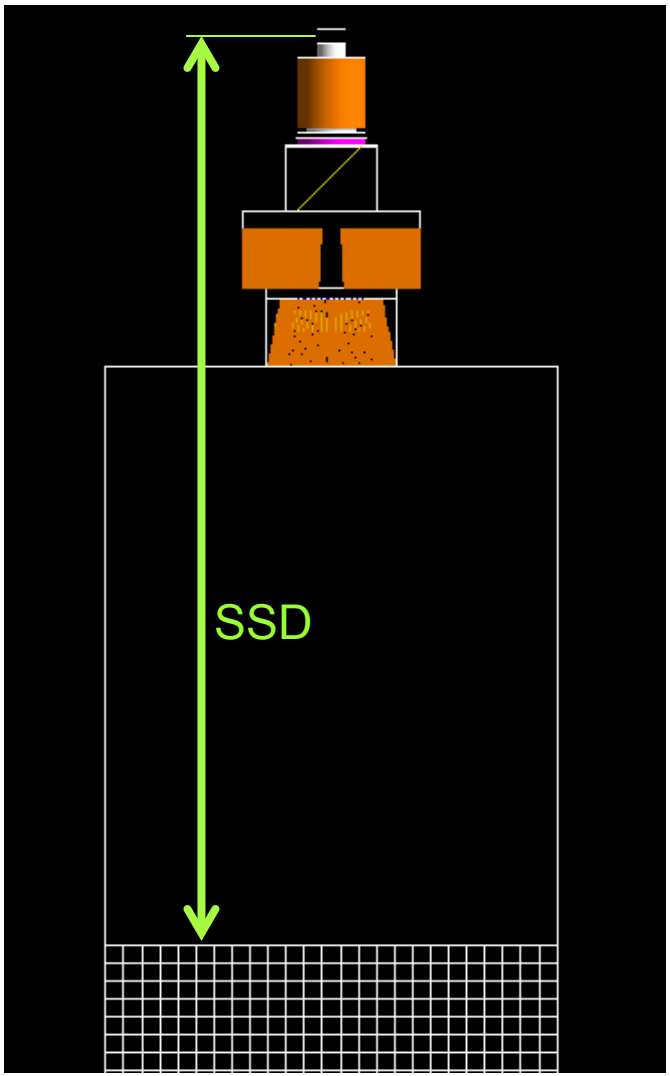
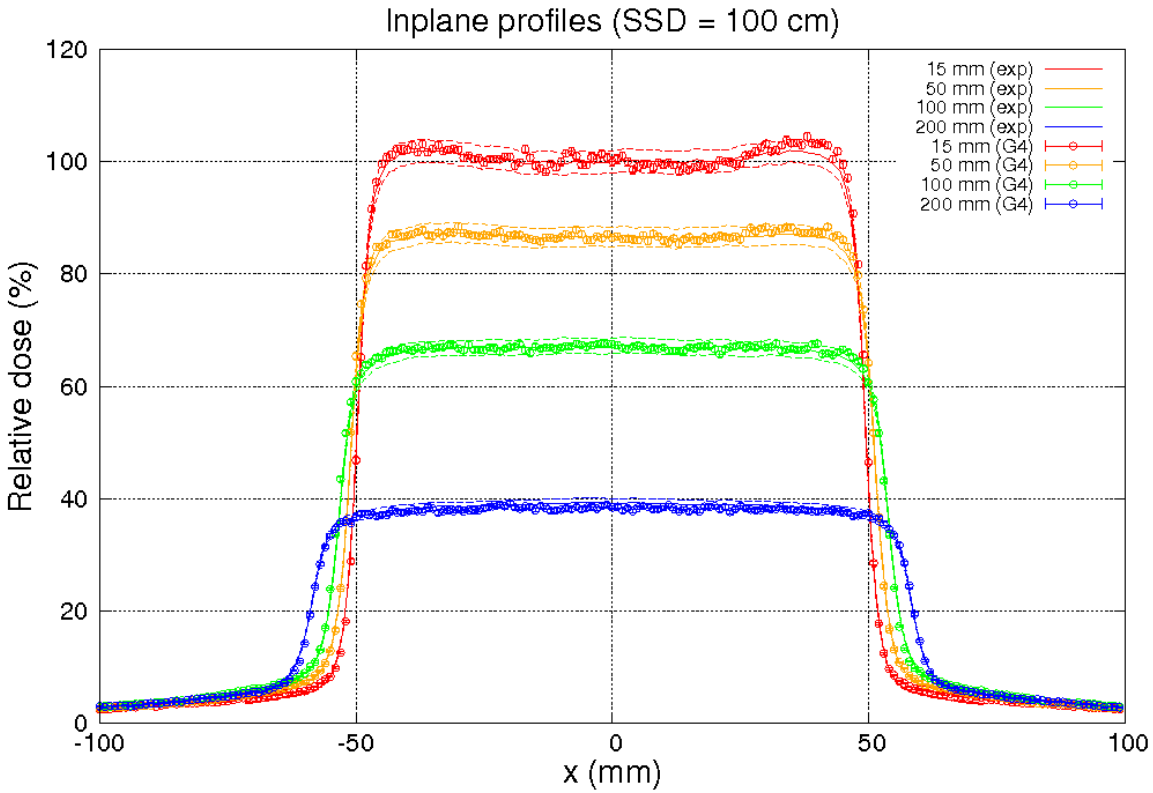


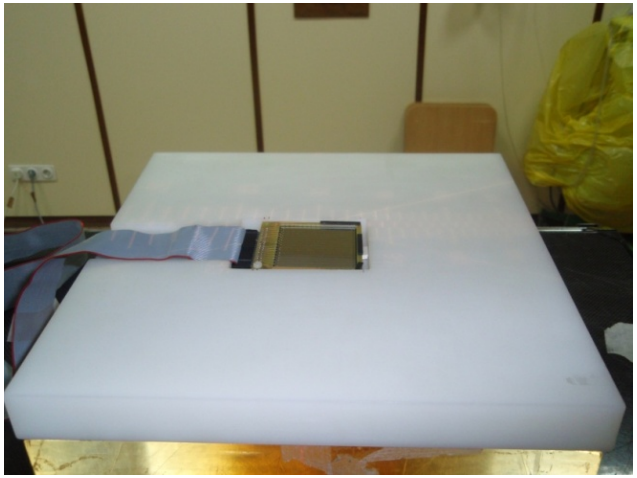
Lateral Profile
(SSD = 100 cm, 10 × 10 cm^2 field)

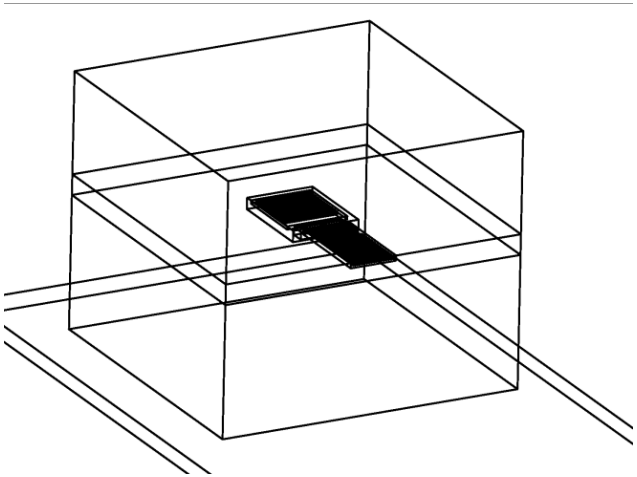


Monte Carlo Simulations

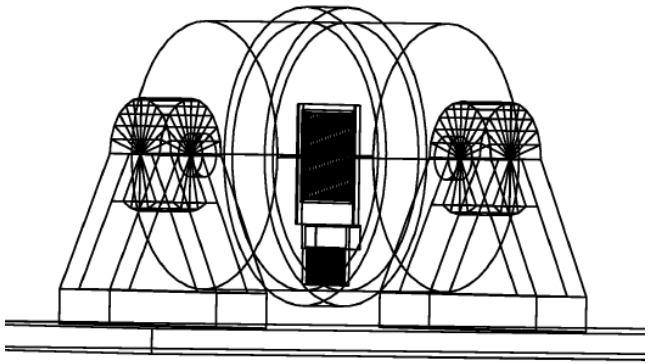
Performed with the Geant4 toolkit

Slab Phantom

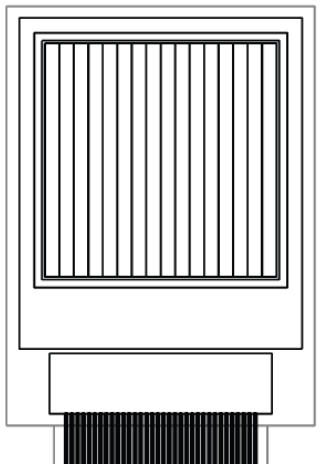




Cylindrical Phantom

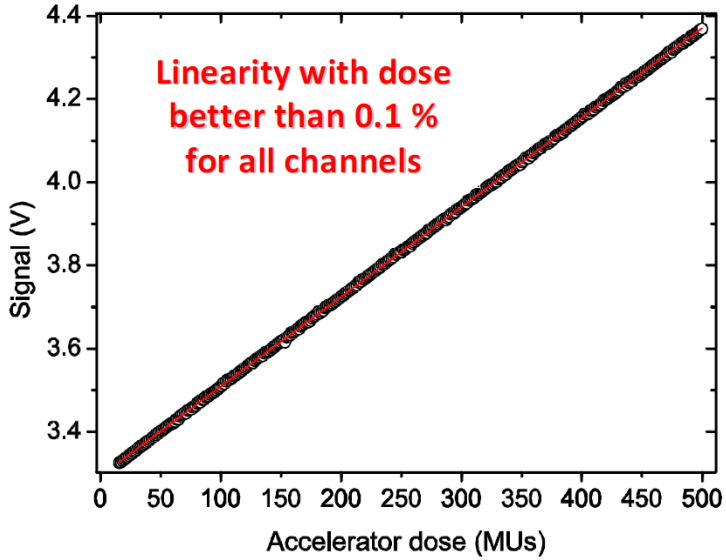


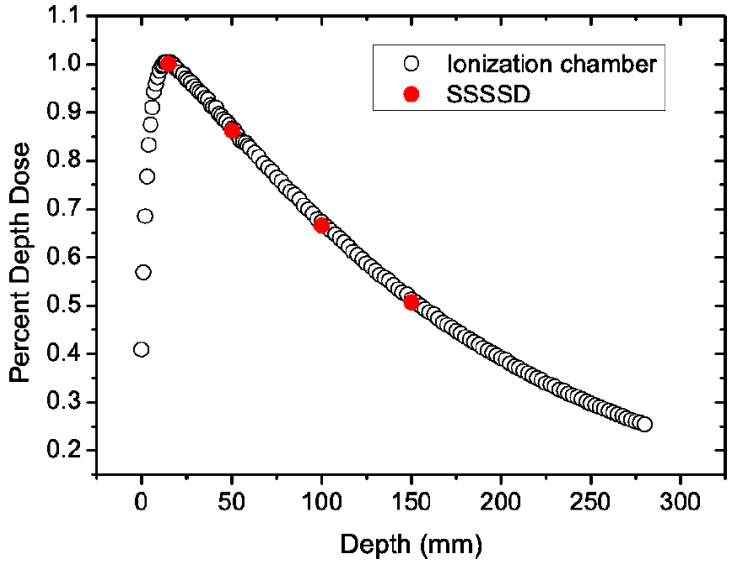
SSSSD Detector

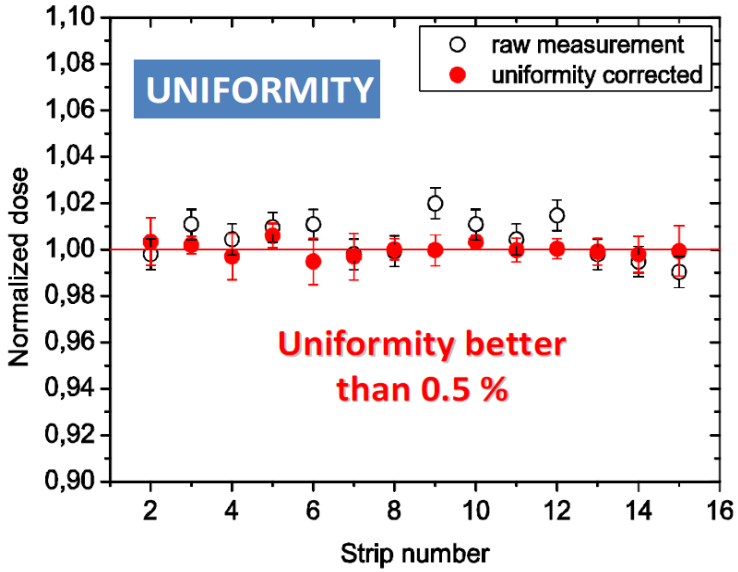


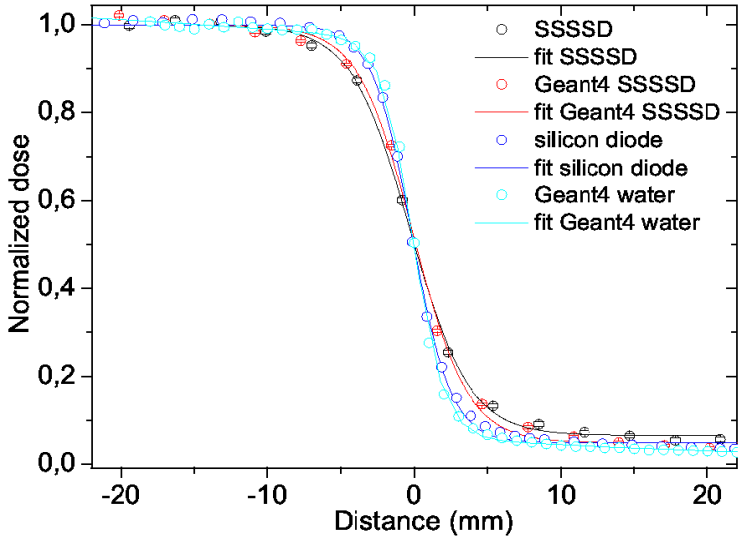
Results

Detector characterization. Slab phantom measurements



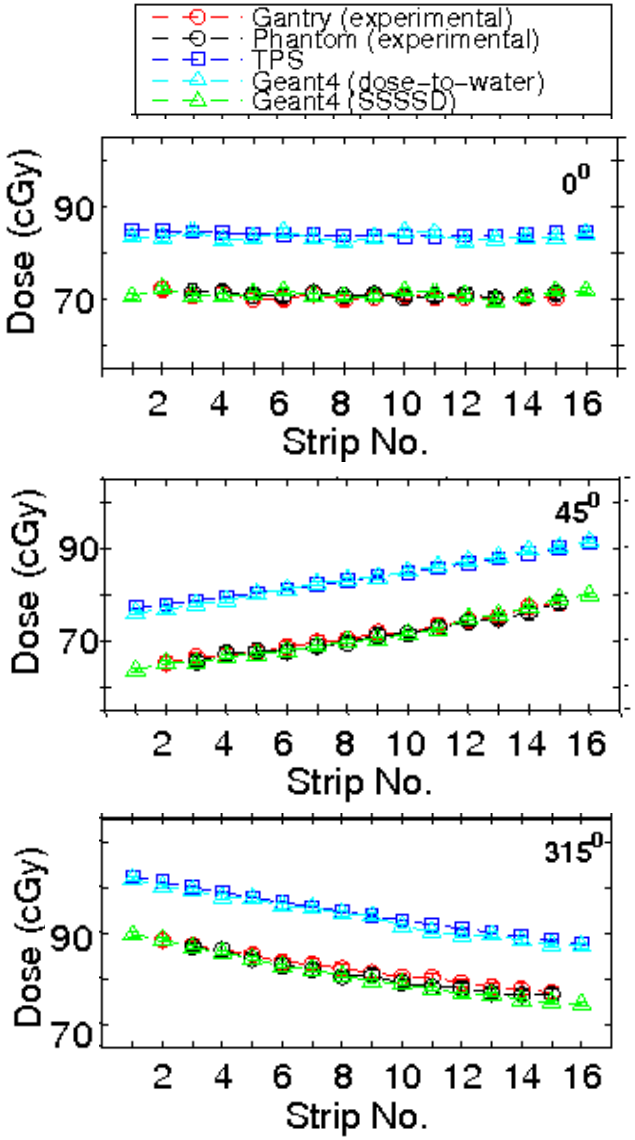


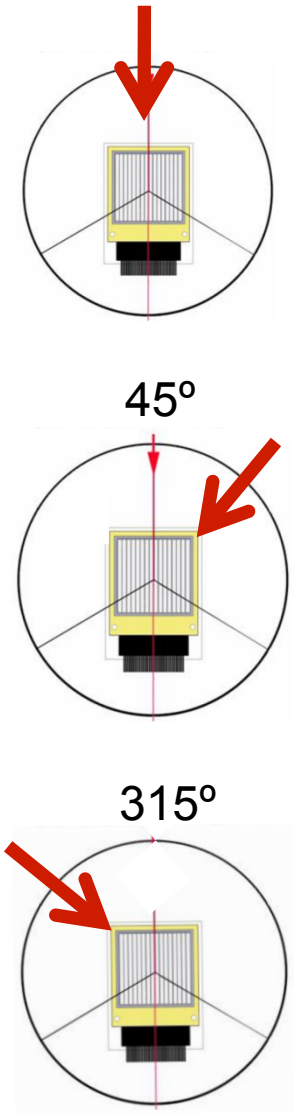




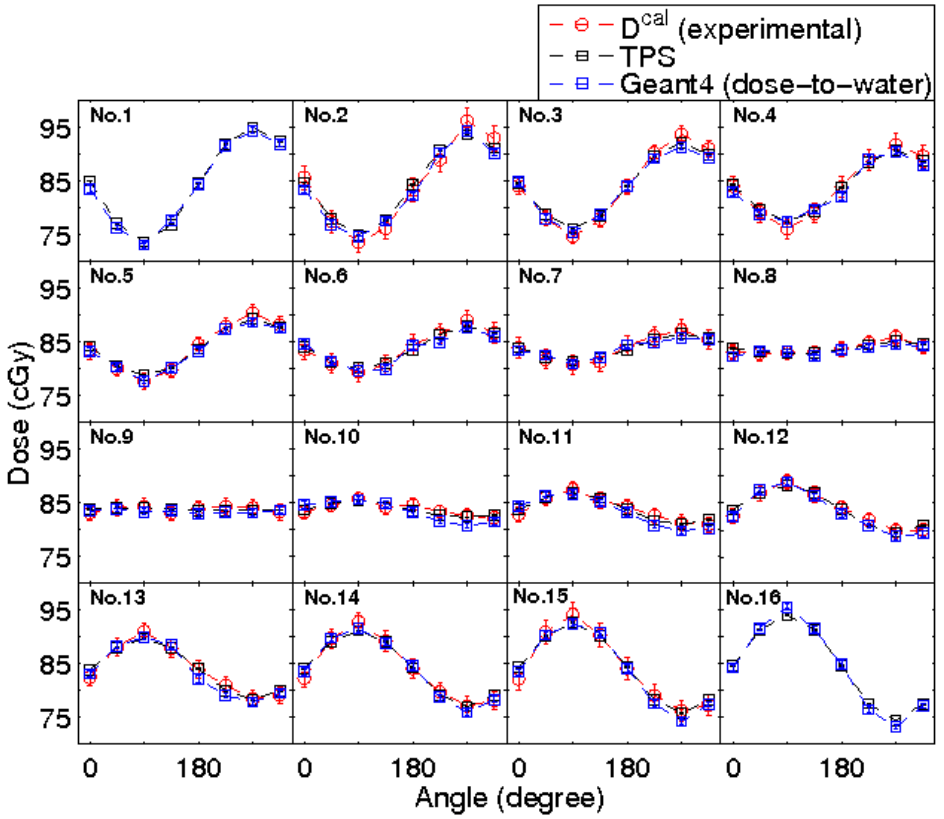
Results

Detector characterization. Cylindrical phantom measurements





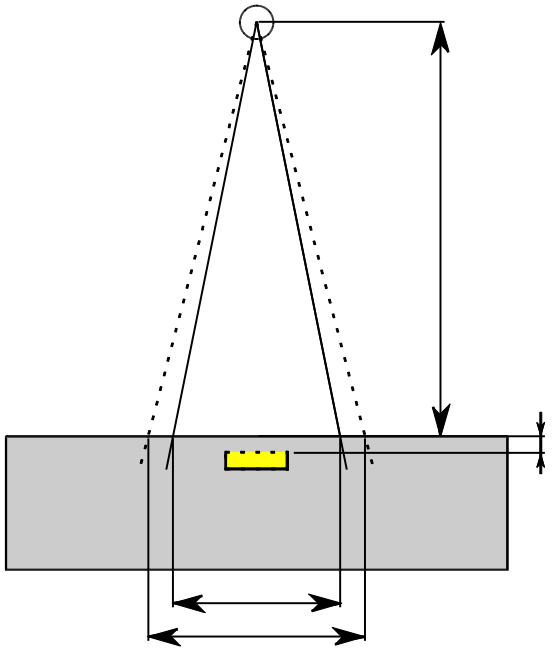
SSSSD parallel
to the beam direction

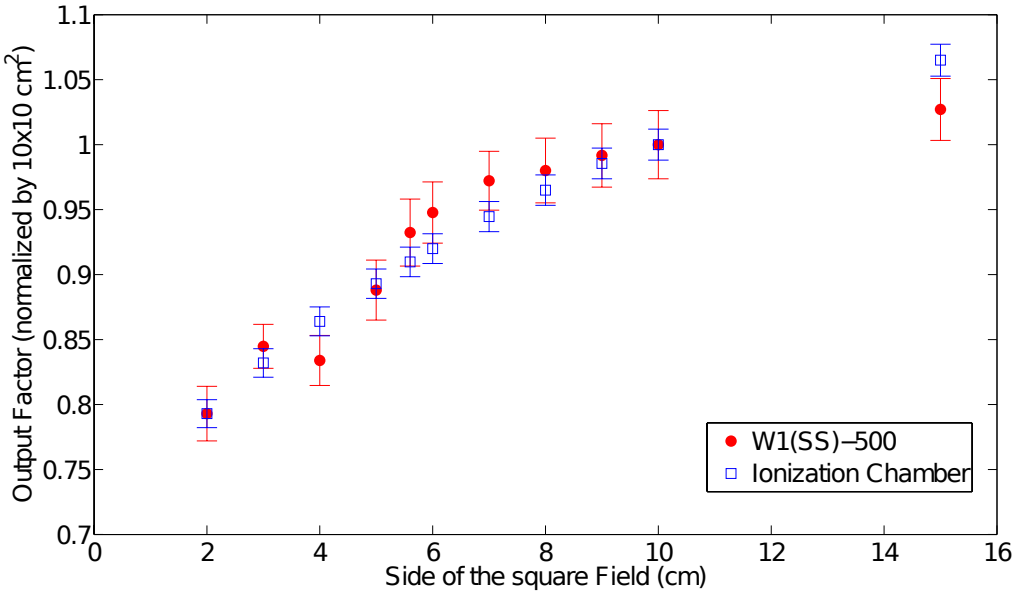


Results

Output Factor measurements. Slab Phantom

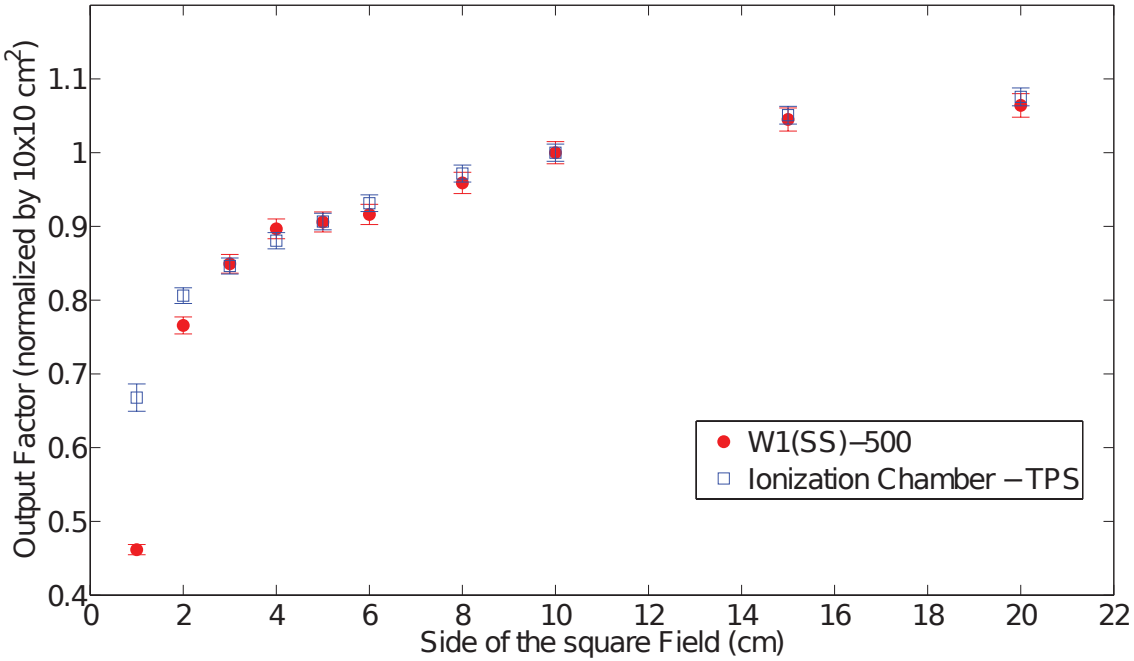
- The output factor (OF) is defined as the ratio of the dose for any field size *A* x *A* cm^2 to the dose for a reference field at the same source to surface distance, and at the same depth *d* in a slab phantom. The reference field is a square field of 10 x 10 cm^2 at SSD of 100 cm.
- Data measured with the silicon strip detector are compatible with the ones given by the TPS and/or by the ionization chamber.

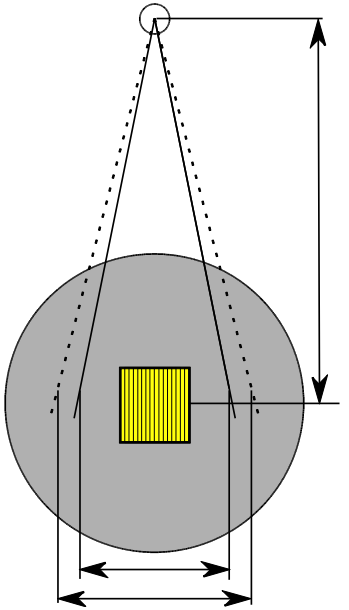




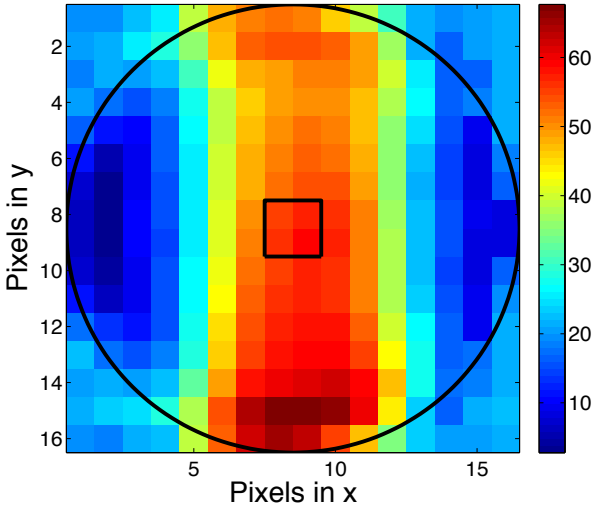
Results

Output Factor measurements. Cylindrical Phantom





Reconstructed Dose Map
2×2 cm^2 field

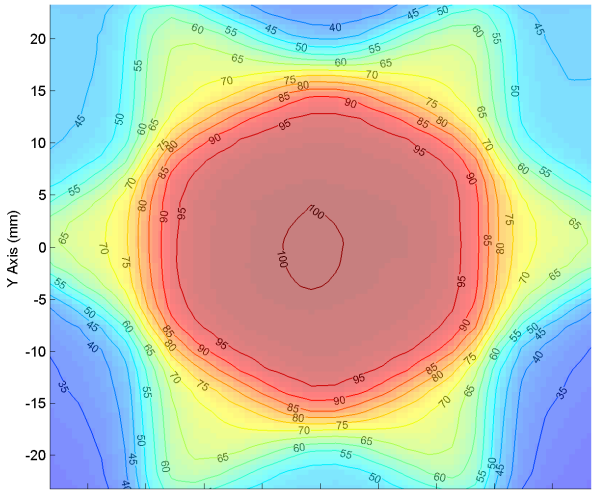


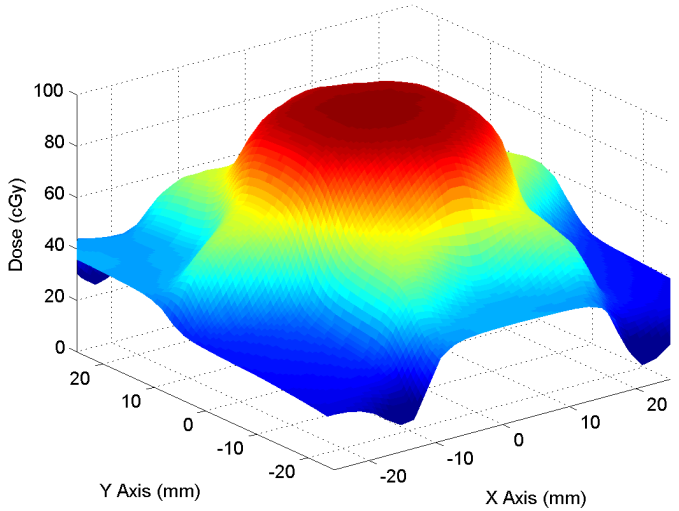
- Data are compatible within the error bars for fields bigger than 2 x 2 cm^2
- For fields of 2 x 2 cm^2 and smaller, data are not compatible. No electronic equilibrium, since the strips and the field are of a comparable size.

Results

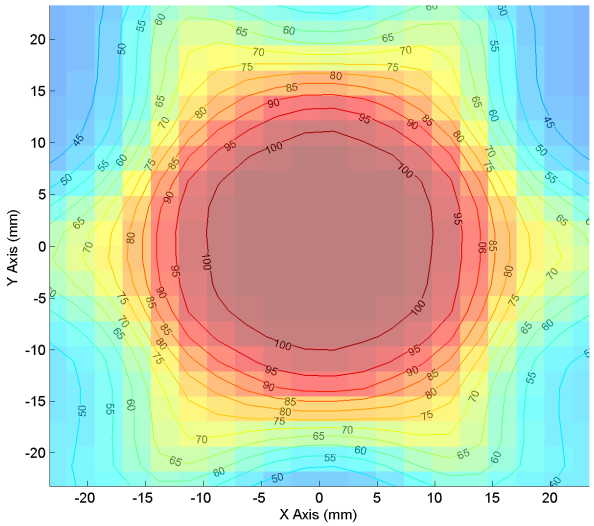
2D Dose Map Reconstruction

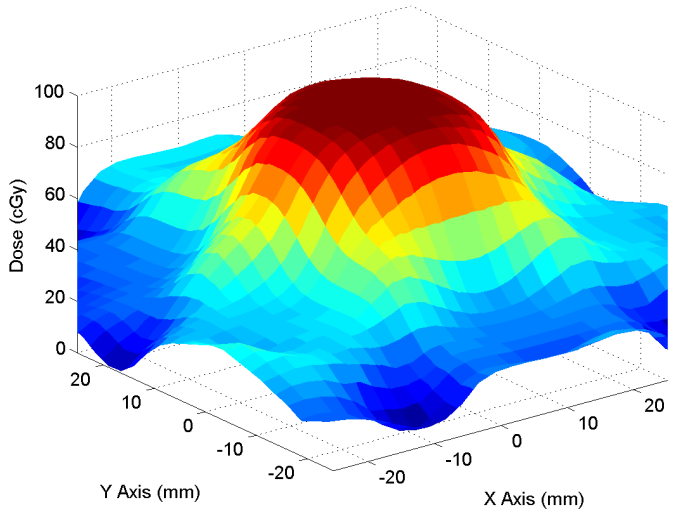
Philips Pinnacle TPS





Reconstructed dose





Conclusions

- **Main Objective: Characterization and benchmarking of a new detection system based on a Si-strip detector dedicated to 2D dose measurements in the axial plane of a cylindrical phantom.**
- **SSSSD characterization: results show that the prototype is suitable for complex RT verification plans (remarkable linearity, uniformity, PDD, OF).**
- **The angular response of the detector in the axial plane is independent of the irradiation angle and of the strip number.**
- **Geant4 simulations are compatible with TPS and experimental measurements.**
- **Comparison between final calibration and TPS in the axial plane presents differences <2% for all the strips.**
- **This system is patent pending.**

Future Developments

- **Future: work is in progress in order to obtain 2D dose maps from experimental data in the axial plane using an in-house developed algorithm based on the Radon Transform.**

- **A new SSSSD prototype together with a new experimental set-up are being built to improve the spatial resolution (2 mm strip width).**

- **Coupling the data acquisition system to the reconstruction algorithm and an on-line user friendly graphical interface software is under development.**

Collaboration

This work would not have been possible without the collaboration of several people from the following institutions:

- **Department FAMN (University of Seville)**
- **Centro Nacional de Aceleradores – CNA, Seville**
- **Hospital Virgen Macarena, Sevilla**
- **School of Engineering of the University of Seville**
- **Instalaciones INABENSA SA, Seville**

References:

- **A. Bocci et al.,** ***"Silicon strip detector for a novel 2D dosimetric method for radiotherapy treatment verification", NIM-A 673: 98-106 (2012).***
- **M. A. Cortés-Giraldo et al., "*Geant4 Simulation to Study the Sensitivity of a MICRON Silicon Strip Detector Irradiated by a SIEMENS PRIMUS Linac", Progress in Nucl. Sci. and Tech. 2: 191-196 (2011).***
- **Z. Abou-Haidar et al.,** ***Output factor determination for dose measurements in axial and perpendicular planes using a silicon strip detector, submitted to PRST-AB, special ed. DITANET conference, Oct 2011.***
- ***Conference ESTRO 2011, Radiation and Oncology, Volume 99 , Supplement 1 (2011).***

THANKS FOR YOUR ATTENTION

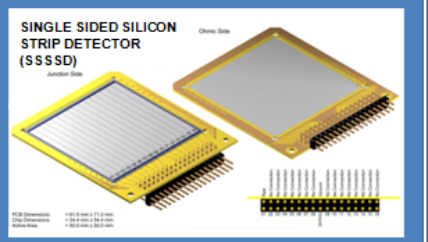
(Abstract 302)

A Novel On-Line Treatment Verification System Based on Silicon Strip Detectors for Measuring 2D Axial Dose Maps in RadioTherapy

M. A. Cortés-Giraldo [1], Z. Abou-Haidar [2], A. Bocci [2], M. I. Gallardo [1], J. M. Espino [1], M. A. G. Alvarez [1,2], J. M. Quesada [1], R. Arráns [3], M. C. Ovejero [1], A. Pérez Vega-Leal [4], F. J. Pérez Nieto [5]

[1] Department of Atomic, Molecular and Nuclear Physics (FAMN), University of Seville, 41012 Seville, Spain.
[2] Centro Nacional de Aceleradores (CNA), 41092 Seville, Spain.
[3] Servicio de Radiofísica, Hospital Universitario Virgen Macarena, 41007 Seville, Spain
[4] Escuela Superior de Ingenieros, University of Seville, 41092 Seville, Spain
[5] Instalaciones Inabensa S.A., 41014 Seville, Spain

The Detector



- Commercial, relatively low cost detector from Micron Semiconductor Ltd, UK
- Single sided 16 strips (3.1 mm pitch)
- Active area 50 x 50 mm² & 500 µm thick
- Good radiation hardness

The Phantoms

Slab phantom | Cylindrical phantom

Two phantom prototypes have been designed and built:

1. A slab phantom for detector characterization
2. A cylindrical phantom for angular response measurements & for 2D dose measurements in complex radiotherapy planning verification.

Clinical Linac

6-MV photon beams produced by PRIMUS and ONCOR Linacs (Siemens)

Discrete electronics: 16 channels

Charge integrators (electrometers) digitized (12 bits) and analyzed by a Digital Signal Processor (DSP).

A PC allows to control and to retrieve data via an RS-232 serial bus (based on LabVIEW platform).